APPENDIX 6-7A

REVISED WATER BALANCE MODEL
ALTERNATIVE EVALUATION SUBMITTED OCTOBER 13, 2005

Additional versions of the WBM developed for the evaluation of alternatives include:

- EAA-A1.xls – This models the EAA Reservoir A-1 with 2010 available flows, environmental deliveries, and agricultural deliveries. The northeast pump station pumps to 12 feet of EAA Reservoir A-1 depth and the G-370 and G-372 pump stations are not modified and pump only to 8 feet of EAA Reservoir A-1 depth.

- EAA-A1_2015_Envtl.xls - This models the EAA Reservoir A-1 with 2015 environmental deliveries, and 2010 available flows and agricultural deliveries. The northeast pump station pumps to 12 feet of EAA Reservoir A-1 depth, G-370 and G-372 pump stations are not modified and pump only to 8 feet of EAA Reservoir A-1 depth.

- EAA-A1_G370_Modified.xls – This models the EAA Reservoir A-1 with 2010 available flows, environmental deliveries, and agricultural deliveries. The northeast pump station pumps to 12 feet of EAA Reservoir A-1 depth, G-370 pump station is modified and pumps to 12 feet of EAA Reservoir A-1 depth, while G-372 pump station is not modified and pumps to only 8 feet of EAA Reservoir A-1 depth.

- EAA-A1_G370_Modified_2015_Envtl.xls - This models the EAA Reservoir A-1 with 2015 environmental deliveries, and 2010 available flows and agricultural deliveries. The northeast pump station pumps to 12 feet of EAA Reservoir A-1 depth, G-370 pump station is modified and pumps to 12 feet of EAA Reservoir A-1 depth, while G-372 pump station is not modified and pumps to only 8 feet of EAA Reservoir A-1 depth.

- EAA-A1+A2_2015_Flows&Demands.xls – This models EAA Reservoir A-1 and EAA Reservoir A-2, and therefore includes 2015 available flows, environmental deliveries, and agricultural deliveries. The northeast pump station pumps to 12 feet of EAA Reservoir A-1 depth, G-370 and G-372 pump stations are not modified and pump only to 8 feet of EAA Reservoir A-1 depth.

- EAA-A1+A2_G370&G372_Modified_2015_Flows&Demands.xls - This models the EAA Reservoir A-1 and EAA Reservoir A-2, and therefore includes 2015 available flows, environmental deliveries, and agricultural deliveries. The northeast pump station pumps to 12 feet of EAA Reservoir A-1 depth, G-370 and G-372 pump stations are both modified to pump to 12 feet of EAA Reservoir A-1 depth.

The results of the main runs for each of these versions are provided on Figures 1A through 6A.

APPENDIX 6-7

WATER BALANCE MODEL ALTERNATIVE EVALUATION SUBMITTED JULY 29, 2005

TABLE OF CONTENTS

LIST OF FIGURES

BLACK & VEATCH

TECHNICAL MEMORANDUM

South Florida Water Management District
EAA Reservoir A-1
Work Order No. 5

B&V Project 141522
B&V File: C-1.3
First Issue: July 15, 2005
Last Updated: July 22, 2005

Task 5.3.6.3.3 Water Balance Model Revised Alternatives Evaluation

To: Shawn Waldeck, Rich Bartlett

From: Rafael Frias and Jeff Henson

1. INTRODUCTION

The purpose of the Water Balance Model (WBM) Revised Alternatives Evaluation report is to provide a revision to the work completed on the model under Work Order 4 and to present the results of the latest alternative evaluated with the WBM.

Updates to the work from Work Order 4 include the following:

- Renaming of key model terms
- Use of new results from the latest South Florida Water Management Model (SFWMM) run for the EAA Reservoir A-1
- Use of new data for reservoir inflows and outflows, including new seepage values
- Updated reservoir characteristics
- New WBM features
- Evaluation of Additional Alternatives

Updates to the previous work and the results of the latest evaluated alternative are discussed in detail in Section 6 of this report.

2. OBJECTIVE

The purpose of EAA Reservoir A-1 is to capture Everglades Agricultural Area (EAA) basin runoff and releases from Lake Okeechobee. The facilities should be designed to improve the timing of environmental water supply deliveries to Stormwater Treatment Area (STA) 3/4 and the Water Conservation Areas (WCAs), reduce Lake Okeechobee regulatory releases to the estuaries, meet supplemental agricultural irrigation demands, and increase flood protection within the EAA. (Hornung et al.)

The overall objectives of the Water Balance Model (WBM) are as follows:

Task 5.3.6.3.3 Water Balance Model Revised Alternatives Evaluation

- To determine the quantity, duration, and timing of releases to the North New River Canal for irrigation needs
- To determine the quantity, duration, and timing of releases to the STA 3/4 Supply Canal for Everglades restoration needs
- To evaluate proposed pumping station location(s) and capacity(ies)
- To evaluate proposed gate location(s) and capacity (ies)

This technical memorandum summarizes the work conducted to develop the WBM including Model Configuration and Data Sources, Model Reliability and Initial Alternative Evaluation to demonstrate the suitability of the model for the analysis of alternatives for the design of the EAA Reservoir A-1.

3. MODEL CONFIGURATION AND DATA SOURCES

See Appendix 5-22.

4. MODEL RELIABILITY

See Appendix 5-9.

5. INITIAL ALTERNATIVE EVALUATION

See Appendix 5-22

6. CONCLUSIONS

See Appendix 5-22

7. UPDATES TO PREVIOUS WORK

As stated in the Introduction, updates to the work from Work Order 4 include the following:

- Renaming of key model terms
- Use of new results from the latest SFWMM run for the EAA Reservoir A-1
- Use of new data for reservoir inflows and outflows, including new seepage values
- Updated reservoir characteristics
- New WBM features
- Evaluation of Additional Alternatives

7.1 Renaming of Key Terms

Key model terms that have been renamed include:

- Holey Land Distribution Canal is now the STA 3/4 Supply Canal West.
- The STA 3/4 Supply Canal includes the STA 3/4 Supply Canal West (supplied by G-372) and the STA 3/4 Supply Canal East (supplied by G-370)
- Environmental Demands are now Flows to STA 3/4
- Period of Record is now Period of Simulation (POS)

7.2 New SFWMM Run

Data for reservoir canal inflows and demand outflows are now based on the results from the District's Office of Modeling (OoM) SFWMM ECP 2010 run for a reservoir with a storage capacity of 190,000 acre-ft, updated in June of 2005.

7.3 New Inflows and Outflows Data

The main input parameters into the WBM include precipitation, reservoir inflows and outflows, evaporation, and seepage. These parameters may be separated into Inflows and Outflows of the reservoir. Data on the parameters were provided by the District's Office of Modeling (OoM) and the United States Army Corps of Engineers (USACE) Interagency Modeling Center (IMC), based on simulations using the SFWMM.

The OoM provided the available flows in the North New River (NNR) canal and the Miami canal, as well as the required flows to STA 3/4 and the agricultural irrigation demands to be supplied by the reservoir, based on the SFWMM ECP 2010 run. The IMC provided evaporation and precipitation data based on the inputs into the SFWMM.

7.3.1 Inflows

Reservoir inflows in the WBM consist of flows from the NNR canal, STA 3/4 Supply Canal West, seepage collection canals, and precipitation. A description of each inflow is provided below.

- **NNR Inflow –** Canal flow from the NNR canal. This value was set to equal the daily average simulated flows at pump station G370, based on the OoM ECP 2010 run. The available flow at G370 is equal to:

$$Flow\ at\ G370 = LKRSN1 + EARIN2$$

Where

LKRSN1 is the excess water from Lake Okeechobee via NNR canal to Compartment 2 of the EAA Reservoir A-1.
EARIN2 is the inflow into Compartment 1 of the EAA Reservoir A-1 from North New River Canal runoff.

- **Canal Inflow** – Canal flow from the STA 3/4 Supply Canal West. The STA 3/4 Supply Canal West branches from the Miami canal and flows east connecting with the EAA Reservoir A-1 along the south half of the west side. Flow at this canal was set equal the flow at pump station G372, based on the OoM ECP 2010 run.

$$Flow\ at\ G372 = LKRSM1 + EARIN2$$

Where

LKRSM1 is the excess water from Lake Okeechobee via the Miami canal to Compartment 2 of the EAA Reservoir A-1.

EARIN1 is the inflow into Compartment 1 of the EAA Reservoir A-1 from the Miami Canal basin runoff.

- **Collected Seepage** – Seepage flows from the EAA Reservoir A-1 collected in the seepage canals. Based on the seepage analysis work performed by Black & Veatch during the Test Cells program, the collected seepage was found to be a function of reservoir water depth and seepage reduction alternative selected. For a scenario with an embankment that includes a 30-ft deep seepage cutoff wall and a 20 ft deep seepage canal, the collected seepage may be approximated with the polynomial equation:

$$Collected\ Seepage = 0.0012x^2 - 0.0464x + 1.0752$$

Where

Collected Seepage is expressed as the percentage of the total seepage from the reservoir collected by the seepage canals.

X is the reservoir water depth in feet.

- **Precipitation** – Mean daily precipitation data were provided by IMC based on the inputs into the SFWMM. Precipitation inputs were for the 10 cells that encompass the EAA Reservoir A-1 footprint. Inflow data was based on actual precipitation values for the POS. The average value of all 10 cells for each day in the POS was used as input data for the WBM.

7.3.2 Outflows

Reservoir outflows in the WBM consist of losses from evaporation, seepage, irrigation demands, flows to STA 3/4, and excess volume flows. A description of each outflow is provided below.

- **Evaporation** – Mean daily evapotranspiration (ET) data (for the POS) for the 10 cells that encompass the EAA Reservoir A-1 footprint were provided by the IMC, based on the inputs into the SFWMM. The ET data used in the SFWMM were compared to historical direct evaporation data. Historical evaporation data were downloaded from DBHYDRO for the area in the vicinity of the EAA Reservoir A-1. The data provided by DBHYDRO is pan evaporation. A commonly accepted conversion of pan evaporation to actual evaporation is 70 percent of the pan evaporation equals actual evaporation. Using this conversion, a comparison of the ET data used in the SFWMM to actual evaporation data revealed little difference between the two values. As a result, the average value of the ET data from all 10 cells was used as the evaporation data for the WBM.

- **Seepage** – Total seepage from the reservoir as estimated by the seepage analysis work performed by Black & Veatch during the Test Cells program. The total seepage varies with reservoir water depth and depends on the seepage reduction alternative selected. For a scenario with an embankment that includes a 30-ft deep seepage cutoff wall and a 20 ft deep seepage canal, the total seepage may be approximated with the linear equation:

$$Total\ Seepage = 25.951x$$

Where

Total Seepage is the total seepage from the reservoir in cfs.

X is the reservoir water depth in feet.

- **Irrigation Demands** – Agricultural irrigation demands in the EAA to be supplied by the reservoir. Irrigation demands data were provided by the OoM based on the ECP 2010 run. The irrigation demands are equal to:

$$Irrigation\ Demands = EARMA1 + EARMA2 + EARNH1 + EARNH2$$

Where

EARMA1 is the outflow from Compartment 1 of the EAA Reservoir A-1 to meet the Miami Canal basin supplemental irrigation demands.

EARMA2 is the outflow from Compartment 1 of the EAA Reservoir A-1 to meet the Miami Canal basin supplemental irrigation demands not met by EARMA1.

EARNH1 is the outflow from Compartment 1 of the EAA Reservoir A-1 to meet the North New River Canal / Hillsboro Canal basin supplemental irrigation demands.

EARNH2 is the outflow from Compartment 1 of the EAA Reservoir A-1 to meet the North New River Canal / Hillsboro Canal basin supplemental irrigation demands not met by EARNH1.

- **Flows to STA 3/4** – Flows to STA 3/4 required from the reservoir to meet a specific environmental demand in the Everglades. Flows to STA 3/4 data were provided by the OoM, based on the ECP 2010 run. The flows are equal to:

$$Flows\ to\ STA\ 3/4 = WCS4S + EVBLSS$$

Where

WCS4S is the surface water outflow from Compartment 2 of the EAA Reservoir A-1 to WCA-3A via STA 3/4 for environmental water supply purposes.

EVBLSS is the subsurface water outflow down to 1.5 ft below land surface from Compartment 2 of the EAA Reservoir A-1 to WCA-3A via STA 3/4 for environmental water supply purposes.

For the water balance analysis, it was assumed that the reservoir would supply the Flows to STA 3/4 before the Irrigation Demands with the storage available, after accounting for evaporation and seepage losses. In addition, it was assumed that during reservoir empty conditions, the available flows in the canals would be used to increase the reservoir's water level over the minimum WSE, before meeting any of the demands.

- **Excess Volume Outflow** – Flows discharged from the reservoir when full and inflows are greater than outflows. These flows are released to maintain the reservoir maximum water surface elevation (WSE).

7.4 Updated Reservoir Characteristics

Updated reservoir updated characteristics include a reservoir with a 26-ft tall embankment, with an interior bench and 3:1 side slopes. The reservoir provides a storage capacity of 184,000 acre-ft at a normal pool depth of 12 ft. The boundary extension along the west side of the reservoir has been eliminated. Figure 27 illustrates the updated footprint of the EAA Reservoir A-1.

7.5 New WBM Features

New features in the WBM worksheet, which is the main screen of the GUI, include:

Model Input Section

- The Review Notes, accessed via the *Review Notes* command button, provides the updated information on the data used in the model.

- The model has now the capability of evaluating different minimum depth requirements in the reservoir, by allowing the user to enter a specific minimum depth, below which demands would not be met.

Model Output Section

- The POS, in days, is now provided.

- New seepage information is provided, including Maximum Total Seepage from the reservoir, Maximum Collected Seepage in the seepage canals, and the Maximum Flow Lost to Seepage.

- Number of Days Flows to STA 3/4 are Met are provided. These are the environmental demands met when the reservoir is over the minimum WSE.
    - The Percentage from the POS and the Percentage of the Demand Met by Volume are also included.

- Number of Days Irrigation Demands are Met. These are the irrigation demands met when the reservoir is over the minimum WSE.
    - The Percentage from the POS and the Percentage of the Demand Met by Volume are also included.

- Number of Days Reservoir is at Maximum WSE has been added.
    - Also includes the Percentage from POS.

Output Graphs Section

- The Storage graph, accessed via the *Storage Graph* command button, includes now a *Graph Zoom Tool* that allows the user to zoom in on the graph by entering a Start Date and an End Date and then clicking on the Zoom Graph command button.

- The Stage graph, accessed via the *Stage Graph* command button, includes now a *Graph Zoom Tool* that allows the user to zoom in on the graph by entering a Start Date and an End Date and then clicking on the Zoom Graph command button.

- The Irrigation Demands graph, accessed via the *Irrig. Demands* command button, includes the Irrigation Demands to be met by the reservoir and the actual Irrigation Demands met over the POS. The worksheet also includes a *Graph Zoom Tool* that allows the user to zoom in on the graph by entering a Start Date and an End Date and then clicking on the Zoom Graph command button.

- The Flows to STA 3/4, accessed via the *Env. Demands* command button, includes the Flows to STA 3/4 to be met by the reservoir and the actual Flows to STA 3/4 met over the POS. The worksheet also includes a *Graph Zoom Tool* that allows the user to zoom in on the graph by entering a Start Date and an End Date and then clicking on the Zoom Graph command button.

7.6 Latest Evaluated Alternative

The latest alternative evaluated with the WBM includes a reservoir with a storage capacity of approximately 190,000 acre-ft at a water depth of 12.1 ft. The reservoir includes a 24-ft tall embankment with an interior bench and 3:1 side slopes.

Reservoir conditions include:

- The reservoir starts empty and attempts to meet 100 percent of the Flows to STA 3/4 and specific irrigation demands.
- 100 percent capture of the available flows in the North New River Canal, STA 3/4 Supply Canal West, and seepage canals for inflow into the reservoir.
- A reservoir minimum depth of 0.5 ft, below which Flows to STA 3/4 and Irrigation Demands cannot be supplied.

7.6.1 Results

The results show that, as a minimum, an additional 250 cfs from the North New River Canal would be required each day for the reservoir to meet 100 percent of the Flows to STA 3/4 and the specific irrigation demands in the EAA. This would result on a reservoir average depth of 10.2 inches and a depth greater than 11.1 inches over 50 percent of the POS. Figures 28 through 34 illustrate the results of the run.

8. REFERENCES

Brion, L. M., May 1999, A Primer to the South Florida Water Management Model (version 3.5), South Florida Water Management District, HSM Department, Water Supply Division.

Brion, L.M. and A. Ali, April 15, 2002, ECP Base Simulation and 2050 with Project Simulation Using the South Florida Water Management Model, South Florida Water Management District MEMORANDUM.

Hornung, L., Brion, L.M., and A. Prymas, undated, EAA Storage Reservoir Project, Identification of the Tentatively Selected Plan.

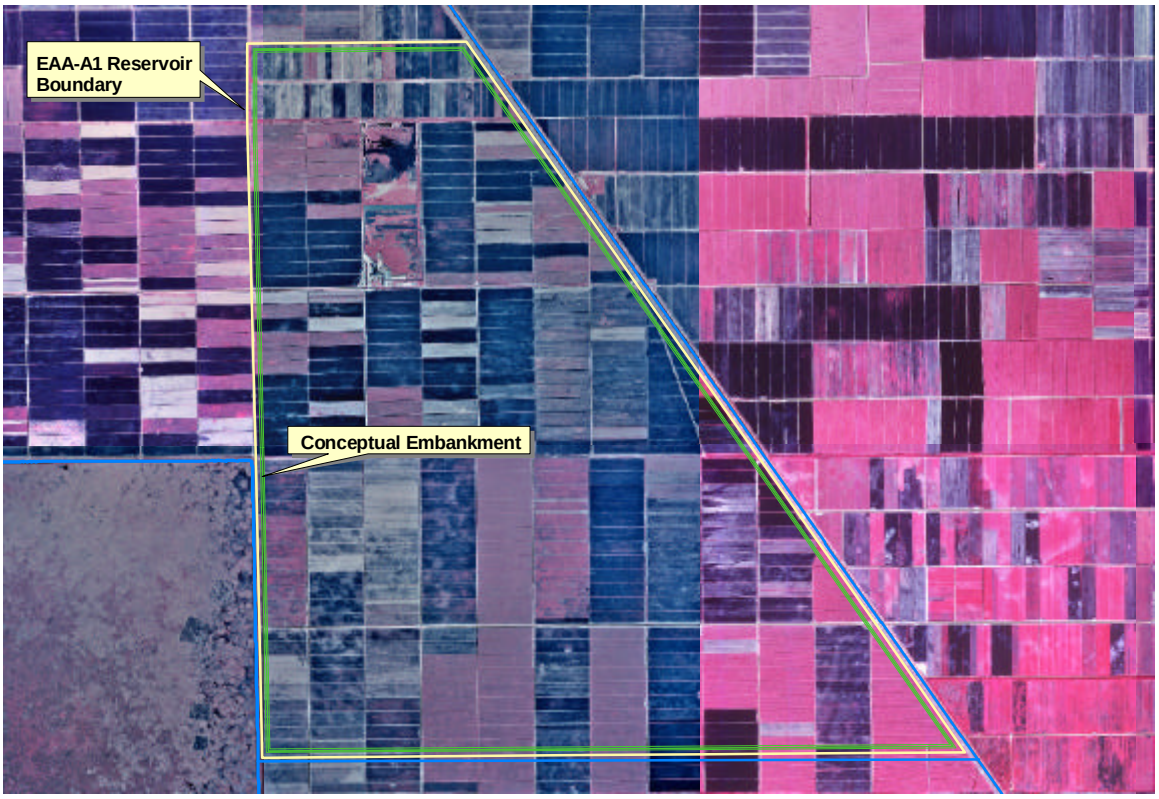
Jacobs/Montgomery Joint Venture, May 20, 2004, Report for Conceptual Levee Height Alternatives, Central and Southern Florida Project, Comprehensive Everglades Restoration Plan, Everglades Agricultural Area Storage A-1 Reservoir Levee Optimization.

Kimley-Horn and Associates, Inc., January 2004, Comprehensive Everglades Restoration Plan, Central and Southern Florida Project, Everglades Agricultural Area Storage Reservoirs – Phase I, B.2 Hydraulics, B.2.3 Hydrologic Model Calibration and Verification.

Kimley-Horn and Associates, Inc., June 2004, Comprehensive Everglades Restoration Plan, Central and Southern Florida Project, Everglades Agricultural Area Storage Reservoirs – Phase I, H, Existing Conditions, H.6 Water Management.

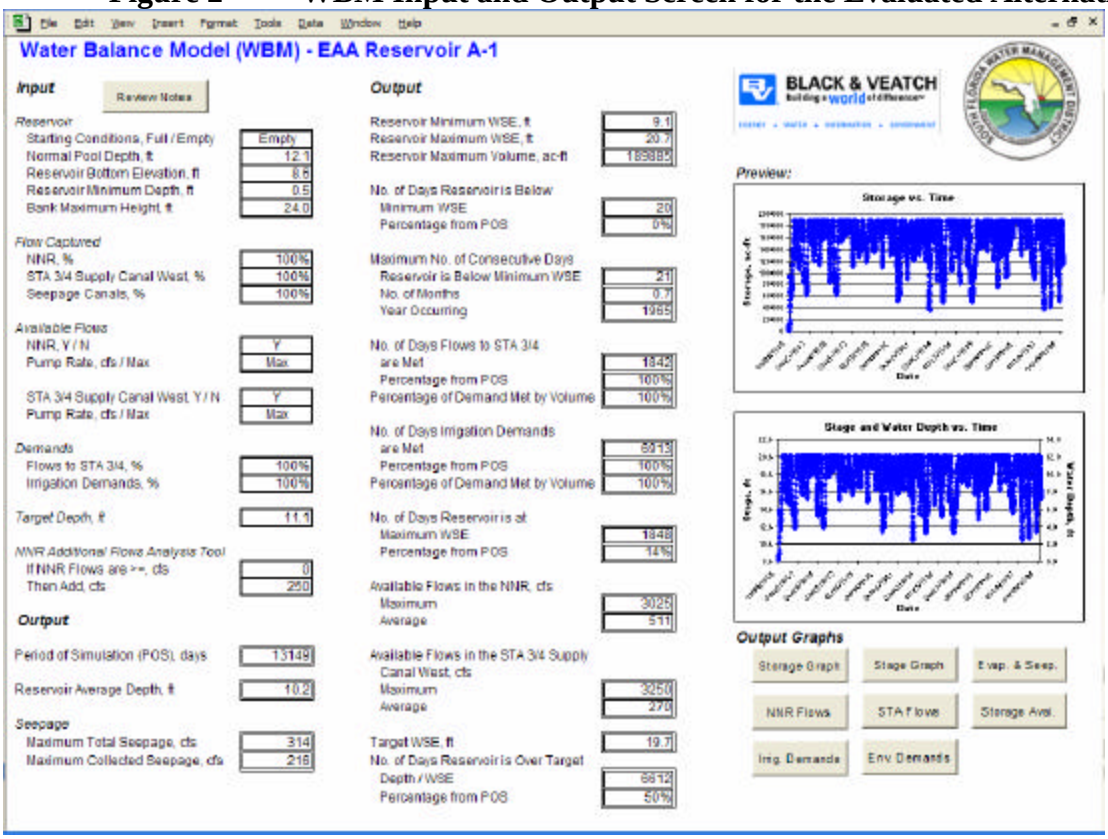
FIGURES

Figure 1 Updated EAA A-1 Reservoir Footprint



Task 5.3.6.3.3 Water Balance Model Revised Alternatives Evaluation

Figure 2 WBM Input and Output Screen for the Evaluated Alternative



Task 5.3.6.3.3 Water Balance Model Revised Alternatives Evaluation

Figure 3 Storage versus Time for the Evaluated Alternative

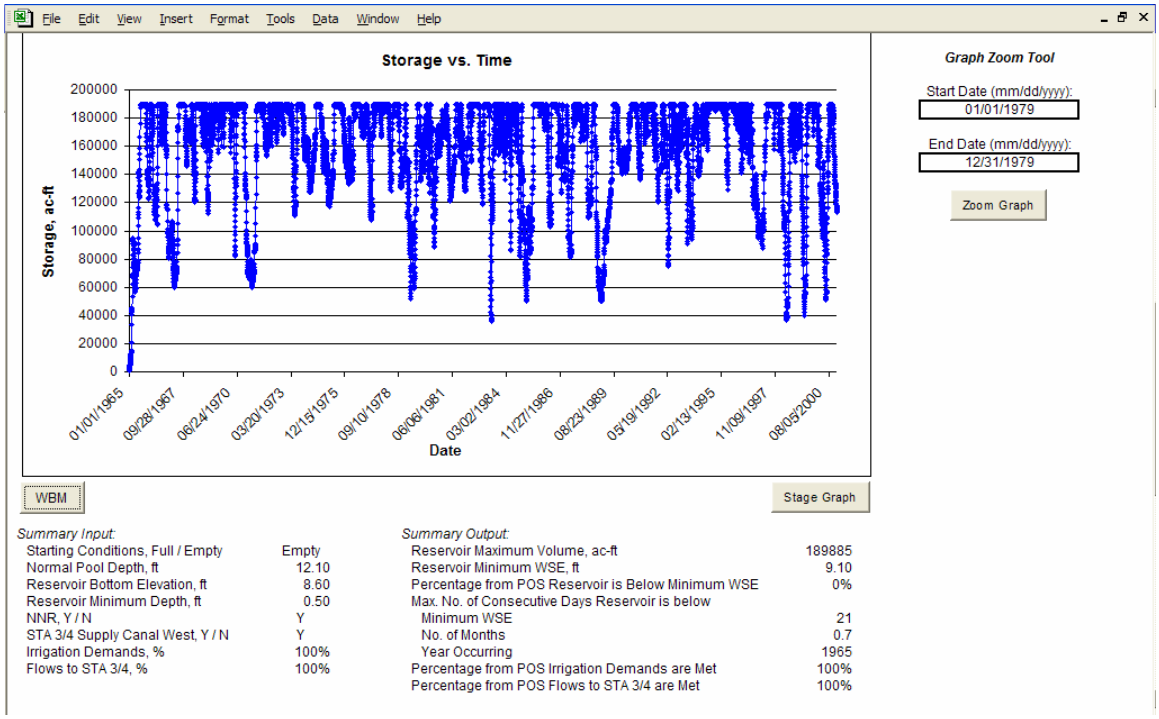
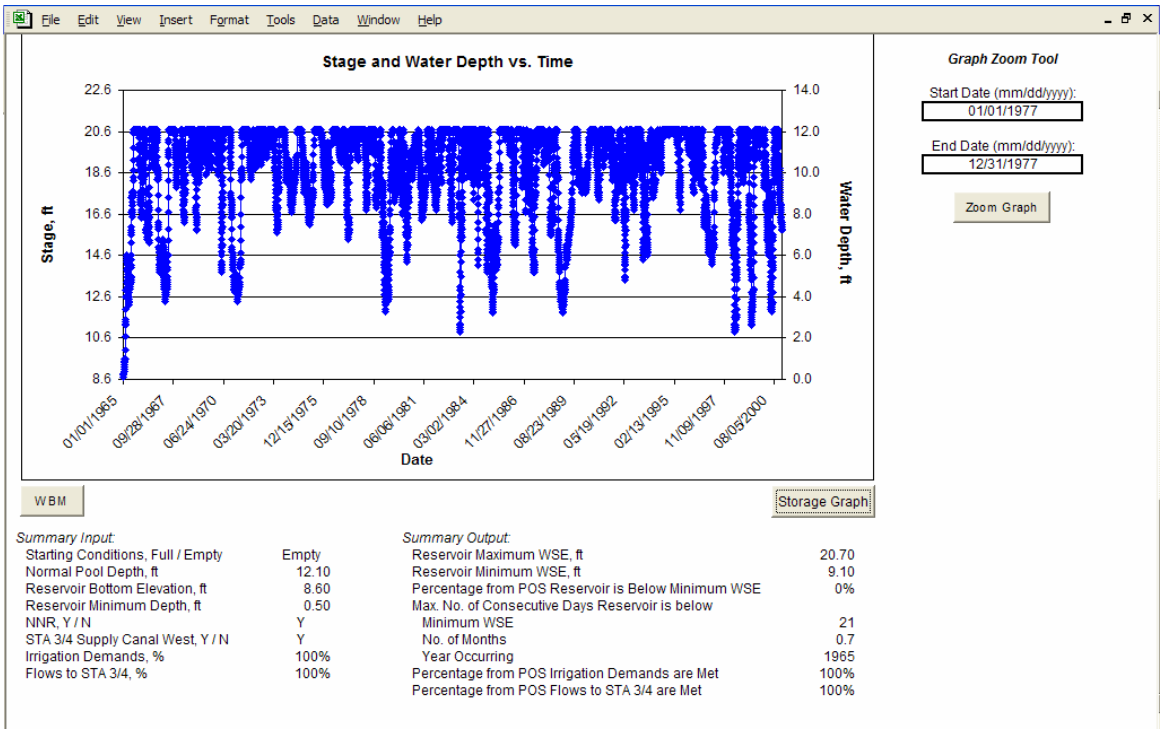


Figure 4 Stage and Water Depth versus Time for the Evaluated Alternative



Task 5.3.6.3.3 Water Balance Model Revised Alternatives Evaluation

Figure 5 North New River Canal Flows versus Time for the Evaluated Alternative

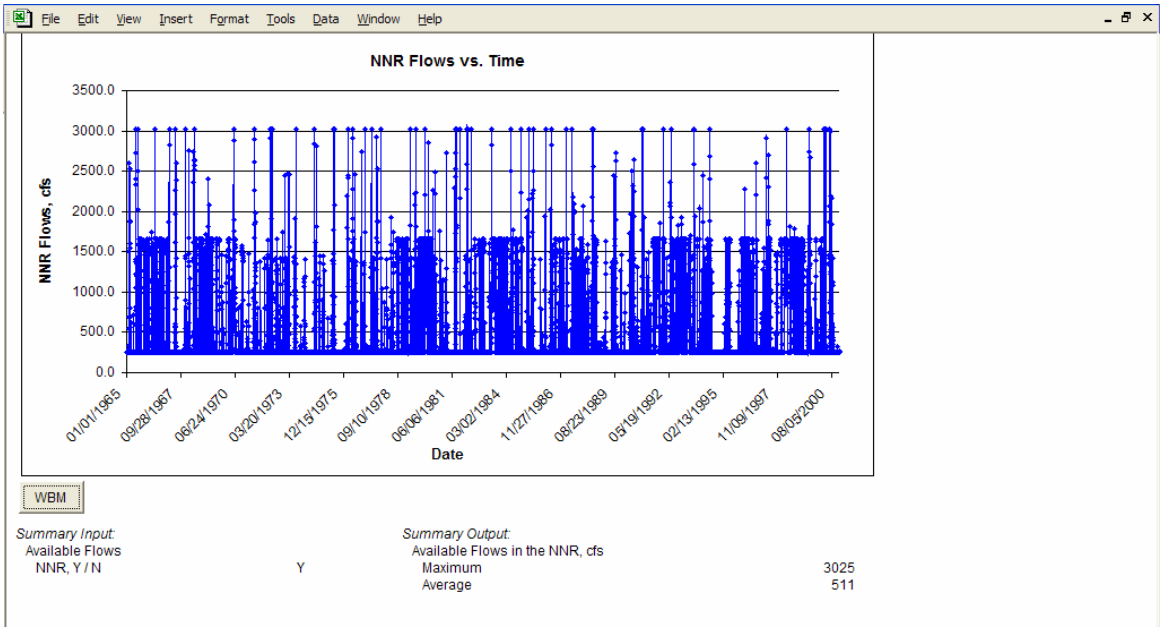


Figure 6 STA 3/4 Supply Canal West Flows versus Time for the Evaluated Alternative

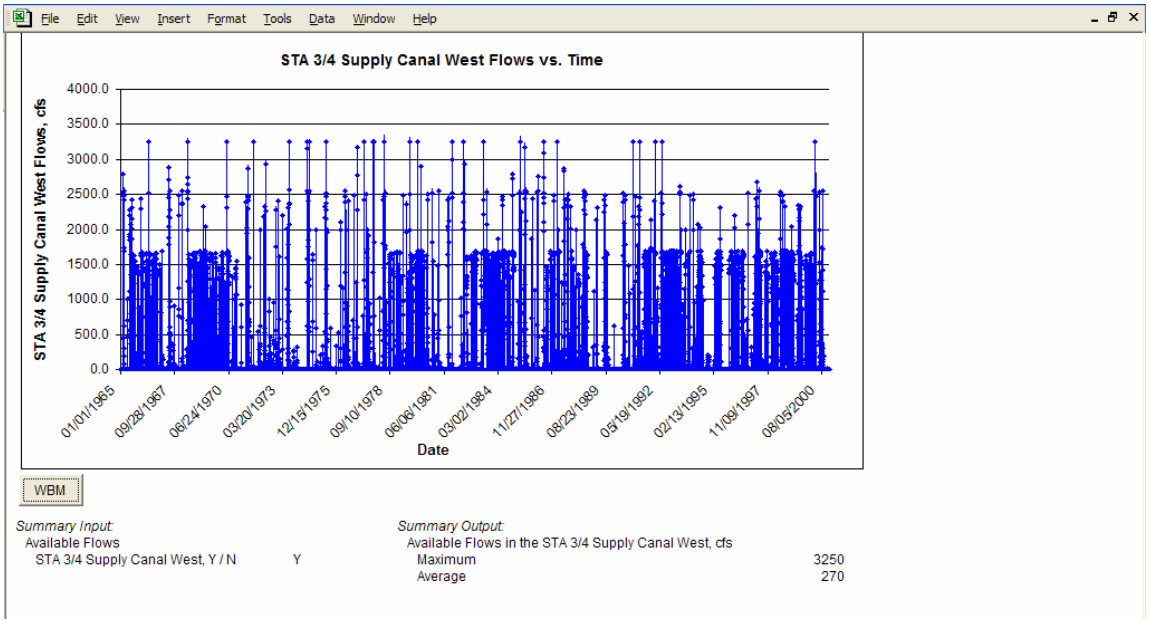


Figure 7 Irrigation Demands and Irrigation Demands Met versus Time for the Evaluated Alternative

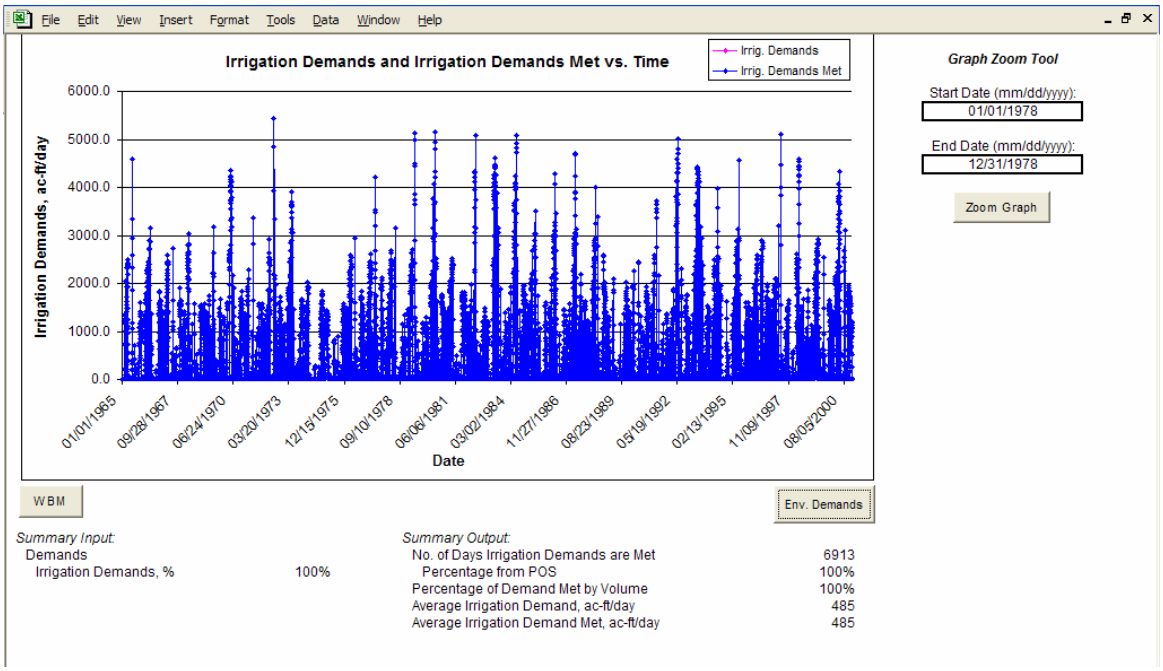


Figure 8 Flows to STA 3/4 and Flows to STA 3/4 Met versus Time for the Evaluated Alternative